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INFORMAL REPORT

THE VARIABILITY OF BOTTOM REFLECTED SIGNALS USING THE DEEP RESEARCH VEHICLE ALVIN

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NAVAL OCEANOGRAPHIC OFFICE
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INFORMAL REPORT

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ABSTRACT*

Two dives were made using the Deep Research Vehicle ALVIN to investigate the variability of normal incidence bottom reflected signals at 12 kHz. The measurements were made over a locally smooth bottom in a water depth of 4750 feet in the Tongue of the Ocean. Approximately 270 bottom reflected signals were recorded at each of three levels above the bottom; 500, 2000 and 4500 feet. For each depth, frequency distributions, autocorrelation coefficients, and coefficients of variation were computed using both relative peak amplitude and energy levels. The results indicate that significant changes in bottom reflectivity can occur in a short duration and that the observed variations are probably caused by changes in the reflective characteristics of the ocean bottom combined with horizontal drift of the vehicle. Changes in the bottom are suggested by the data collected at the deepest level, which exhibits a pronounced shift in signal level and a bimodal frequency distribution of pulse amplitudes. In addition, the observed fluctuations generally increase with increasing distance above the bottom.

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INTRODUCTION

The echo-sounder and other normal incidence reflection systems are essential tools in the study of marine geology and geophysics. During the past few years various studies have been conducted using echo-sounders to determine techniques for classifying sea floor sediments based on the nature of bottom reflected signals; however, during the course of these and other propagation studies, large fluctuations are often observed in echo characteristics from echo to echo. Breslau (1965), using a 12-kHz echo-sounder, indicated the existence of a relationship between the acoustic and geologic properties of the ocean bottom. Smith and Li (1966) suggested that the interpretation of echo-sounder records should be made with care when attempting to identify sediment type by the use of an echo-sounder. Gazey (1963) and others have observed that normal incidence bottom reflected echoes, obtained by using echo-sounders, can fluctuate rapidly in both amplitude and shape when a ship is underway or at anchor. This paper presents the results of a preliminary study using a deep research vehicle to investigate the cause of acoustic fluctuations observed in normal incidence bottom reflected signals.

BACKGROUND

The U. S. Naval Oceanographic Office is currently evaluating the characteristics of various deep research vehicles as platforms for conducting scientific measurements. It was decided that during the course of these evaluations an experiment could be performed from a deep research vehicle to investigate the magnitude of fluctuations of bottom reflected signals, since the vehicle could serve as a stable platform free of the influences and fluctuations that often result when making measurements from the surface. Subsequently, as one part of the evaluation program, the Deep Research Vehicle ALVIN was available for the conduct of such an experiment.

Since advance notice of the opportunity to use the DRV ALVIN was short, there was no time to calibrate the echo-sounder transducer aboard the vehicle, nor was there sufficient time to obtain and install a separate calibrated transducer; however, it was decided that an interesting and useful experiment could be performed using the vehicle's echo-sounder to investigate acoustic fluctuations present in normal incidence bottom reflected signals, since a determination of absolute signal levels would not be required.

DESCRIPTION OF EXPERIMENTAL GEOMETRY AND PROCEDURES

The experiment was conducted during September 1966 over a locally smooth bottom in the Tongue of the Ocean at approximately 24°57'N and

77°37'W in a water depth of about 4750 feet. The experiment location is shown in Figure 1. Two dives were made in the DRV ALVIN in the conduct of the experiment. The first dive was used to gain familiarity with operating procedures and conditions, and no useful measurements were made during this dive. This dive was also used to take a preliminary look at the bottom. The bottom at this location was observed to be smooth, although no photographs were taken. Previous sediment analyses from this area indicate the bottom to be composed of coarse grained sediments.

The bottom reflectivity measurements were made during the second dive. The measurements were made as ALVIN hovered, subject to drift, at three levels above the bottom; 500, 2000, and 4500 feet. The measurements began at the lowermost or 500 foot level. The experimental geometry is illustrated in Figure 2. Since ALVIN does not usually remain submerged for more than eight hours per dive, the data collection time at each level was restricted to about 45 minutes. Measurements were made at ten second intervals, or approximately 270 bottom reflected signals were recorded on magnetic tape at each level. The acoustic output of ALVIN's echo-sounder is a 12-kHz pulse having a duration of about 0.2 millisecond, and a beam width of 30 degrees.

The magnetic tapes were played back through a data processing system composed of a band-pass filter, a delay line and trigger circuit, a squaring and integrating circuit, and an oscilloscope and oscilloscope camera. The data were analyzed to determine relative peak amplitude and energy levels. Signal-to-noise ratios were greater than 10 dB for all data, the worst case being 12 dB occurring at the 4500 foot level.

AMPLITUDE FLUCTUATIONS

The fluctuations of the successive relative peak amplitudes at each level above the bottom are illustrated in Figure 3. These time fluctuations have been normalized so that the 0 dB value corresponds to the mean of each record. The standard deviation in deciBels and the relative standard deviation at each level are also given. The relative standard deviation or coefficient of variation is defined as the ratio of the standard deviation to the mean. The data at the 500-foot level exhibits a pronounced shift of about 7 dB occurring in less than 4 minutes (200 seconds) approximately half-way through the record. The mean value and standard deviation, given for each of the 3 levels, represent values for the entire record; however, it might be more realistic to view the 500-foot record as consisting of two separate records end-to-end and treat each separately. The overall standard deviation is ±4.2 dB for this level.

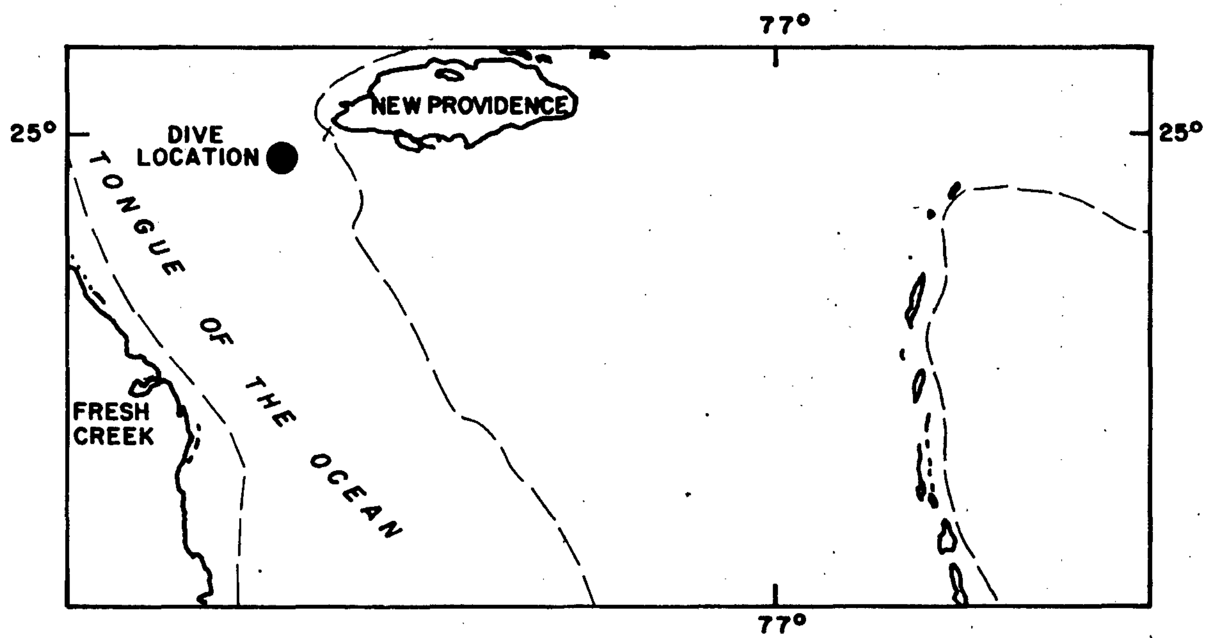

FIGURE 1 LOCATION OF DRV ALVIN DIVES

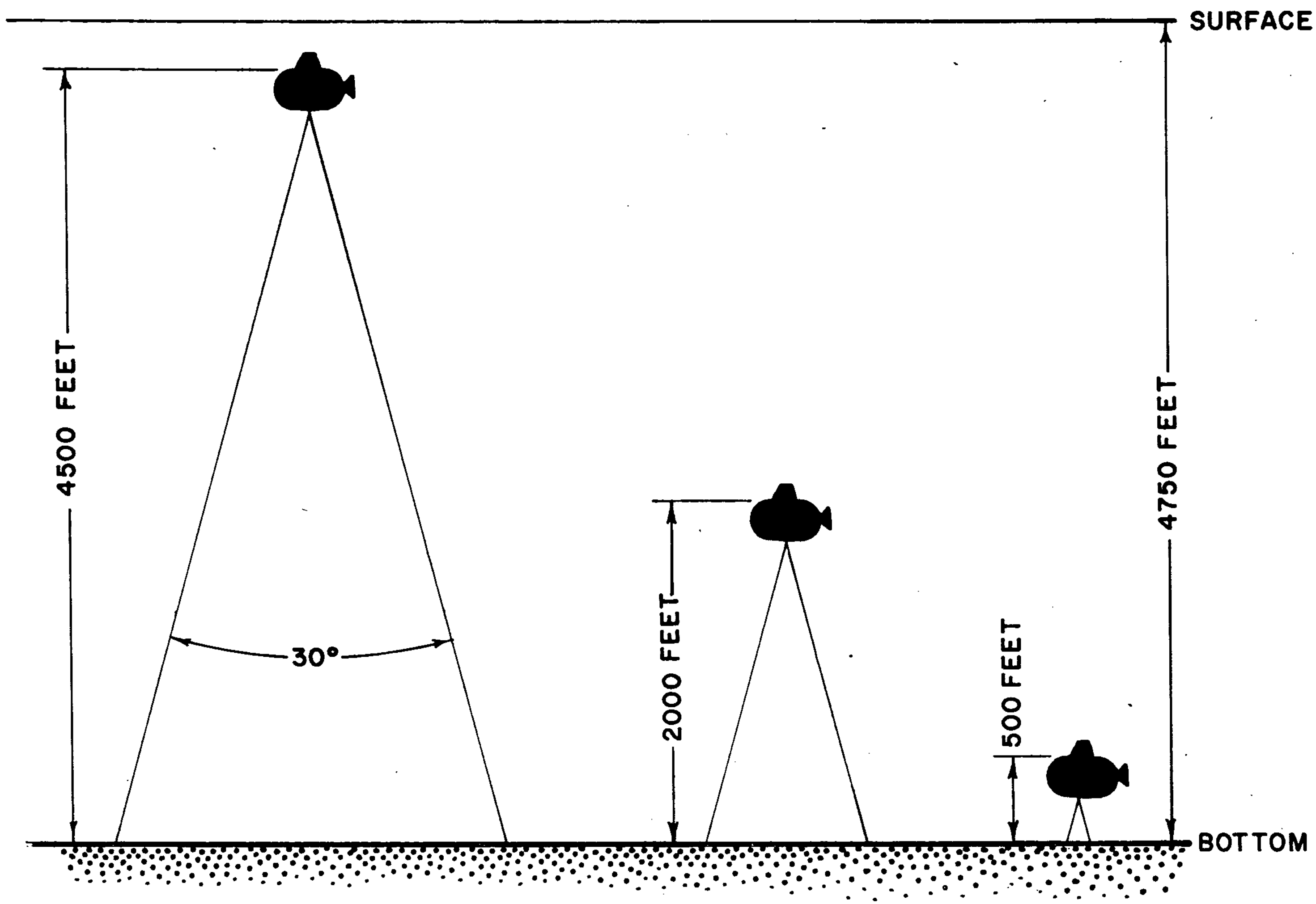

FIGURE 2 EXPERIMENT GEOMETRY. DRV ALVIN AT 500, 2000, AND 4500 FEET ABOVE BOTTOM

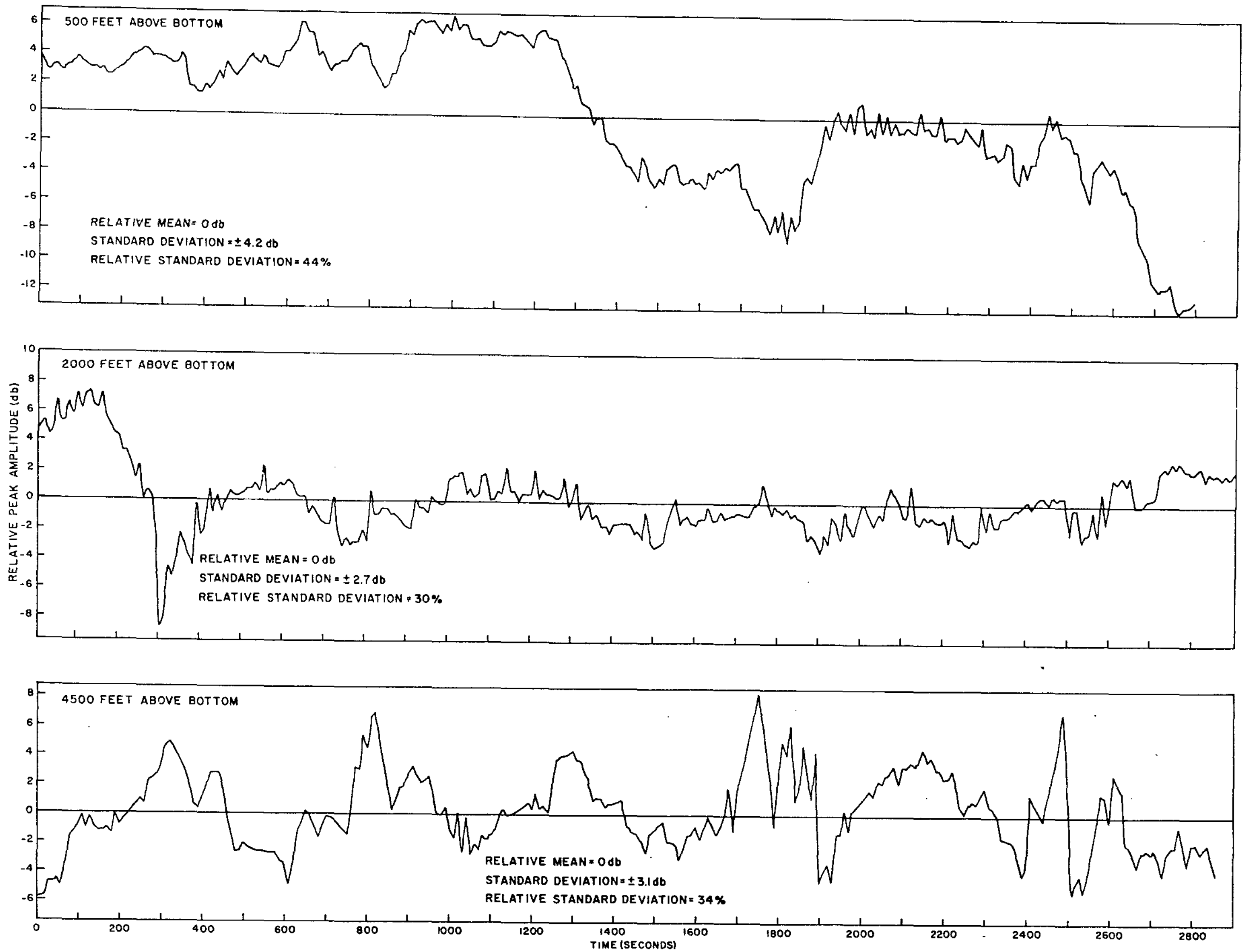

FIGURE 3. TIME FLUCTUATIONS OF RELATIVE PEAK AMPLITUDE IN DECIBELS

The data at the 2000-foot level also shows a large shift in the record, although this shift occurs at the beginning. Because of the similarity of the shifts occurring at these two levels, it is possible the same mechanism may be responsible for both. It can be seen from both the 500 and 2000-foot data that periods of relatively small fluctuations exist for as long as about 7 minutes before more significant variations are observed.

The most pronounced fluctuations occurring for the three levels are seen at the 4500-foot level, with 10 dB variations taking place within a few minutes; however, these fluctuations are in contrast to the definite shifts in amplitude observed at the 500 and 2000-foot levels. The standard deviation at this level is ± 3.1 dB.

Histograms of the peak amplitudes in volts at each level above the bottom are shown in Figure 4. The indicated means have not been adjusted for differences in gain and should, therefore, not be compared. The frequency distributions of the pulse amplitudes for both the 2000 and 4500-foot levels both exhibit right skewness, although neither can be approximate by a Rayleigh distribution. The frequency distribution of the pulse amplitudes for the entire data record at the 500-foot level is markedly bimodal, as would be expected from inspection of the time-series record.

Figure 5 combines the time-series data record and the histogram for the data at the 500-foot level. Although the two halves of the record appear to be somewhat similar in appearance, it nevertheless can be seen clearly that there is approximately a 7 dB difference between the mean values of the first and second halves. There also is a slight increase in the fluctuations occurring during the second half, which is shown by an increase in the standard deviation from ± 1.4 dB for the first half to ± 2.2 dB for the second half.

Figure 6 shows the standard deviation versus distance or range above the bottom. By treating the 500-foot data as two separate records, it can be seen that the magnitude of the fluctuations increases with increasing distance above the bottom.

A comparison of the relative peak amplitude and energy fluctuations occurring at 2000 feet above the bottom is given in Figure 7. The peak amplitude fluctuations represent the peak level in the first 0.2 millisecond, while the energy levels represent the energy in a 2 millisecond window. It can be seen that the agreement between the peak and energy values is very good with the greatest differences occurring at 2600 seconds. This agreement shows that most of the energy reflected within the first few milliseconds is contained within the specular peak. It also indicates that

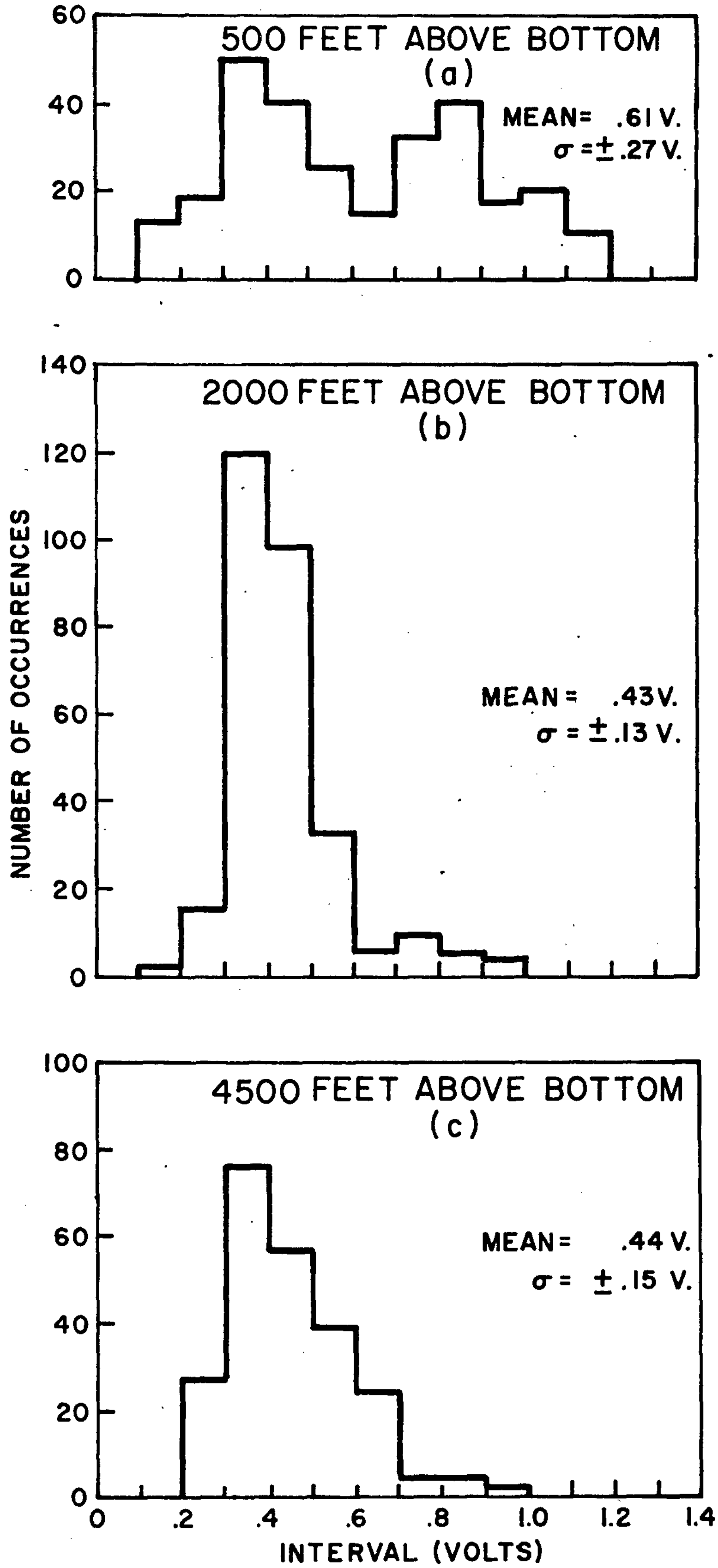

FIGURE 4 HISTOGRAMS OF PEAK AMPLITUDES FOR (A) 500, (B) 2000, AND (C) 4500 FEET ABOVE THE BOTTOM

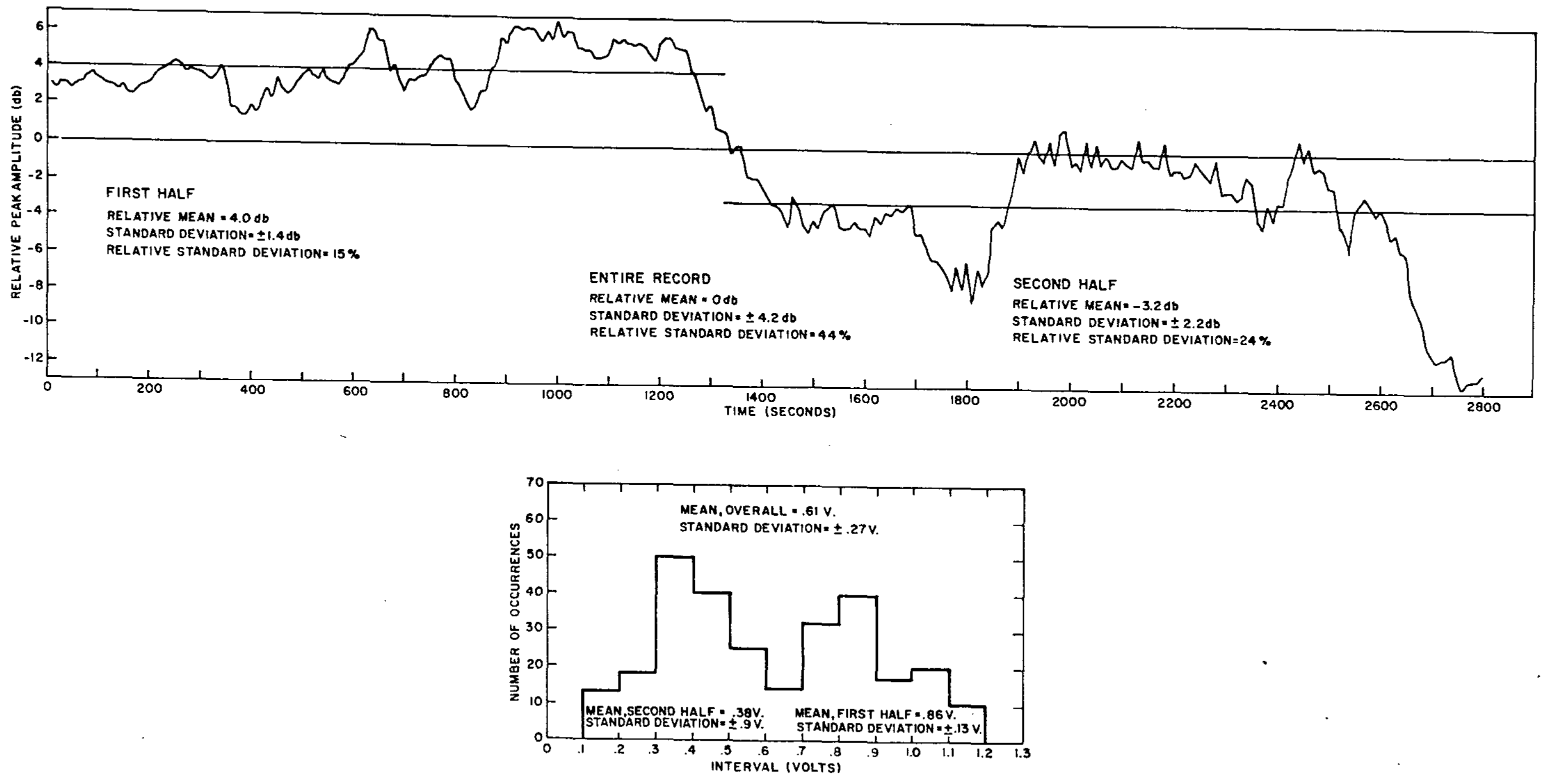

FIGURE 5. FLUCTUATIONS AND BIMODAL FREQUENCY DISTRIBUTION OF PEAK AMPLITUDE AT 500 FEET ABOVE THE BOTTOM

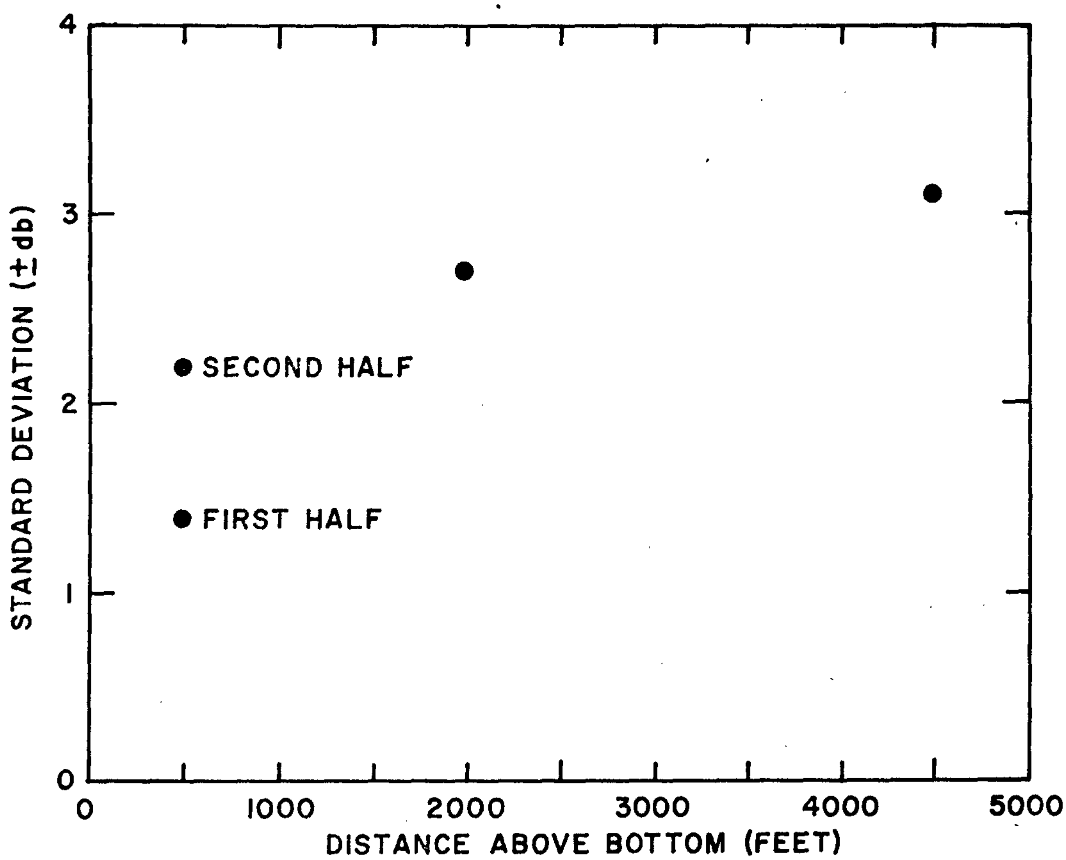

FIGURE 6 STANDARD DEVIATION VERSUS DISTANCE ABOVE THE BOTTOM

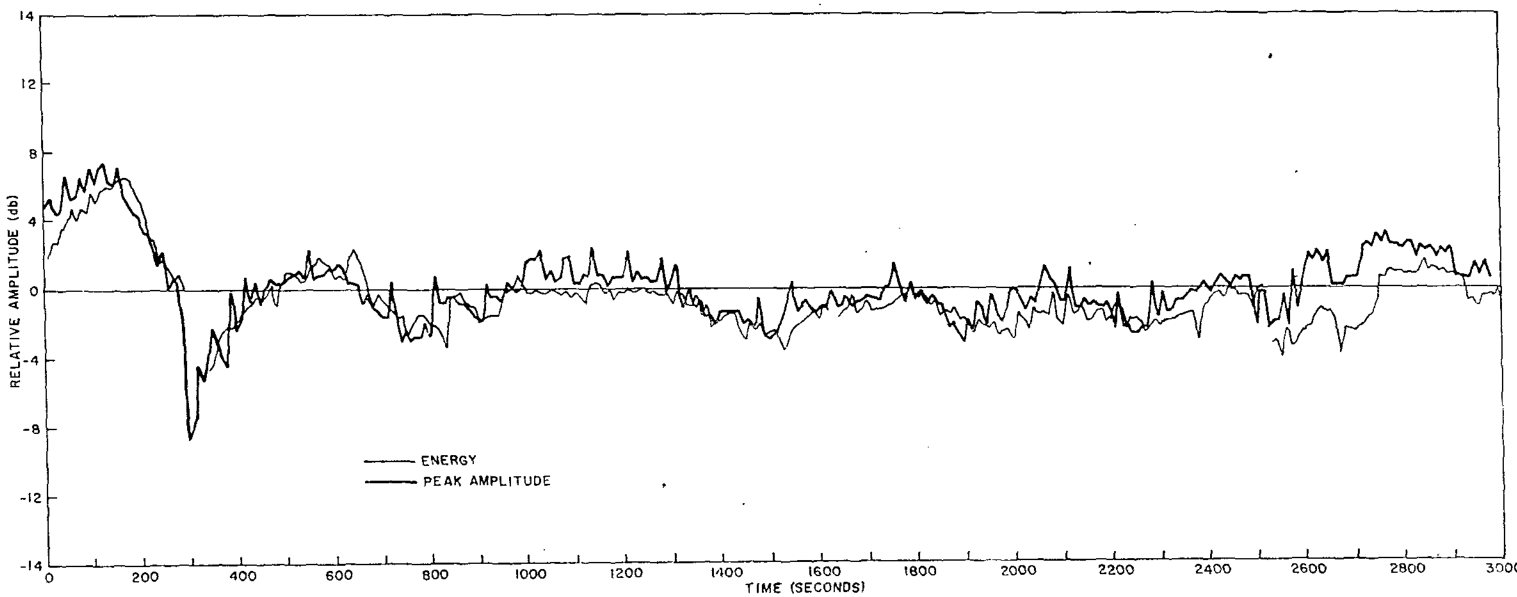

FIGURE 7. COMPARISON OF PEAK AMPLITUDE AND ENERGY FLUCTUATIONS AT 2000 FEET ABOVE THE BOTTOM

there are apparently no significant subbottom reflectors present within the upper five feet of sediment nor is there a significant amount of scattered energy present after the specular peak. Good agreement was also found for the data collected at the 4500-foot level (not shown). Energy calculations were not made for the 500-foot level because of processing difficulties for these data.

PERIODIC TRENDS

In order to resolve possible periodic trends in the data, autocorrelation coefficients for the pulse amplitudes were calculated for the data recorded at each level. The autocorrelation coefficients as a function of correlation interval are shown for each level in Figure 8. Because of the bimodal nature of the data at the 500-foot level, these data are treated as two separate records. It can be seen from these graphs that distinct differences exist between the three levels. Pronounced periodic effects are not apparent for either half of the data record at the 500-foot level; however as can be seen there is a definite difference between the two halves of the record. The autocorrelation coefficient decreases more rapidly for the first half of the data than for the second half, indicating that the fluctuations occur more rapidly during the first half. The pulse amplitudes for the second half of the 500-foot data record are well correlated and vary with correlation interval in a regular fashion. There is also a trace of a 5-minute period (300 seconds) in the first half, which is slightly evident in the data itself (Figure 5).

The autocorrelation graph at 2000 feet shows evidence of a period of about 7 minutes (400 seconds). This period is more apparent for the energy data and can be observed in the time-series fluctuation data shown in Figure 7.

It can be seen that periodic trends in the data become more evident with increasing distance or altitude and pronounced periodicity occurs at the 4500-foot level. Periods occur at intervals of approximately 8 and 16 minutes (480 and 930 seconds). The autocorrelation coefficient decreases most rapidly for these data, indicating an increase in the rapidity of the fluctuations when the DRV ALVIN was nearest to the surface. While the periodicity shown in this graph is probably real, it should be pointed out that this type of analysis is generally valid only if the correlation interval is short compared to the length of the record. A record length of about 2800 seconds usually means that the maximum correlation interval should be approximately 300 seconds. Therefore, there is a possibility that the periodicity of the fluctuations is spurious.

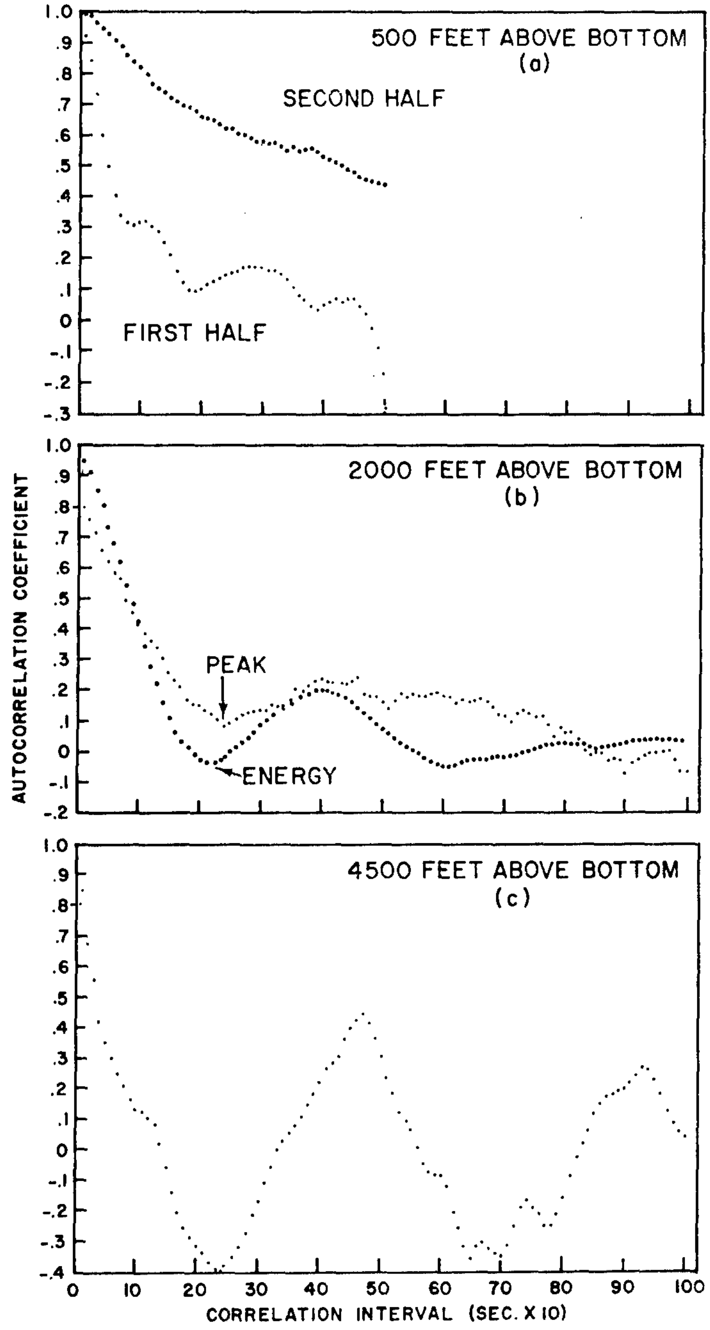

FIGURE 8. AUTOCORRELATION OF PEAK AMPLITUDES AT (a) 500, (b) 2000, AND (c) 4500 FEET ABOVE THE BOTTOM

In an attempt to resolve the possible cause of the observed periodic trends and fluctuations, the vertical separation between the DRV ALVIN and the bottom was determined for each pulse at each level. It is not known whether variations of the vehicle's distance above the bottom results from a sloping bottom or if the vehicle was experiencing vertical movement. Although the dive location was selected because it appeared to be locally smooth, this area does exhibit a regional slope toward the center of the Tongue of the Ocean. If it is assumed that the bottom is flat, at the 500-foot level ALVIN had an average sink rate of about 0.5 feet/minute. At the 2000-foot level, where periodic trends first become evident, the vehicle experienced little vertical motion. At the 4500-foot level, about 250 feet below the surface, the DRV ALVIN underwent a number of vertical oscillations of about 200 feet having an average period of about 15 minutes.

The vertical displacement of the vehicle at any level would have a small effect on the size of the insonified area, so that there would not be a significant percentage increase in the number of scatterers in the insonified area. In addition, since the individual pulse shapes remained unusually consistent from ping to ping and from level to level, the effects of scattering are assumed to be small. It appears that in the aforementioned context there is no apparent relationship between the observed fluctuations and periodic trends at any level and the vehicle's vertical movement; however, it is nonetheless possible to hypothesize that at the 4500-foot level, the periodic fluctuations are related to ALVIN's vertical motion. For example, it is possible that the apparent vertical movement resulted from an orbital motion, rather than pure vertical oscillation, with each complete orbit taking about 15 minutes and having a vertical displacement of about 200 feet. This type of movement could result from an increase in near surface currents and the influence of the surface layer, which extends to a depth of about 200 feet. Vehicle motion of this type would result in a fluctuation period of about 7.5 minutes, which is very close to the computed 8 minute period, as ALVIN made a half orbit and passed over essentially the same part of the bottom approximately every 8 minutes.

Since little vertical motion was observed at the 2000-foot level it is difficult to use the foregoing explanation to resolve the periodic variations at that level, although the fluctuation periods for the 2000 and 4500-foot levels are almost equal.

The roll and pitch of the DRV ALVIN was initially monitored during the early portion of the acoustic measurements, but was found to be negligible and was subsequently discontinued. In this sense, ALVIN did serve as an acoustically stable platform as had originally been anticipated.

Other possible causes of acoustic fluctuations, such as variation in transmission due to bubbles and marine organisms, thermal microstructure and turbulence, variation in power output of the transducer, variation in the acoustic coupling between the transducer and the water, and milti-path interference effects were all investigated and discounted as having no significant influence on the observed fluctuations.

DISCUSSION

It is most probable that the observed fluctuations result from a combination of horizontal drift of the vehicle and changes in the reflective characteristics of the bottom. Pronounced changes in the bottom are suggested by the data collected at the 500-foot level, where a 7 dB amplitude shift and a bimodal frequency distribution of pulse amplitudes occurs. Although horizontal drift of the vehicle was not monitored during the measurement period, it can be assumed that the vehicle experienced horizontal movement according to existing currents. Sub-surface and surface currents in excess of 0.3 knot have been measured at a nearby location in the Tongue of the Ocean. Consequently, it is possible that the vehicle may have traversed in excess of 0.2 of a nautical mile at any level during the measurement period Looking at this in another way the vehicle may have drifted 5 feet between measurements. While these horizontal displacements are not unusually large, they can be extremely significant in an area that is geologically complex, such as the Tongue of the Ocean. Therefore, changes in the reflective characteristics of the bottom, such as sediment composition and roughness, could explain the observed fluctuations and amplitude shifts; however, it should be noted that the observed fluctuations increase with increasing distance above the bottom, indicating the possible influence of other mechanisms. This trend is in general agreement with other studies, which show that the variability of direct transmission increases with range.

From Figure 9 it can be seen that the dive location coincides with a sedimentary boundary, defined by Busby (1962), between axial and near-flank sediments in the Tongue of the Ocean. Three cores, also indicated in Figure 9, were found to be in close proximity to the dive site. A comparison of the near-flank and axial sediment properties is presented in Figure 10, and it can be seen that significant differences exist between the sediments. Since the measurements began at the 500-foot level in all likelihood, at this level, the vehicle drifted across or along the sedimentary boundary. This is a reasonable explanation for the observed bimodal frequency distribution of pulse amplitudes and for the similar amplitude shift that occurred at the 2000-foot level.

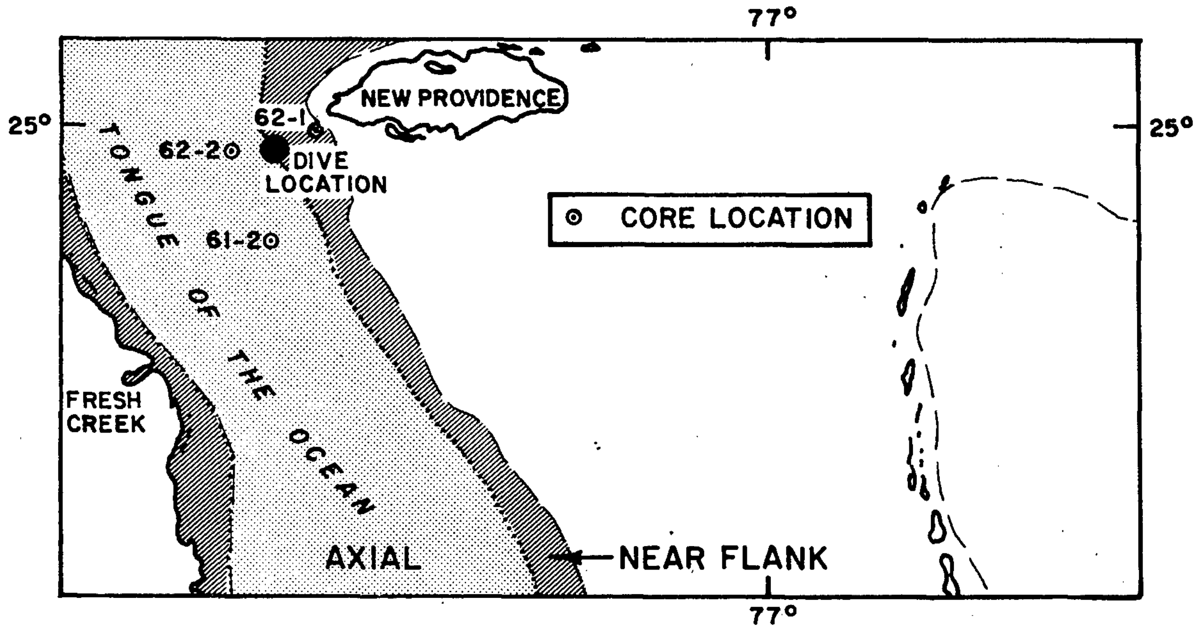

FIGURE 9 DISTRIBUTION OF SEDIMENT TYPES AND CORE LOCATIONS IN THE TONGUE OF THE OCEAN

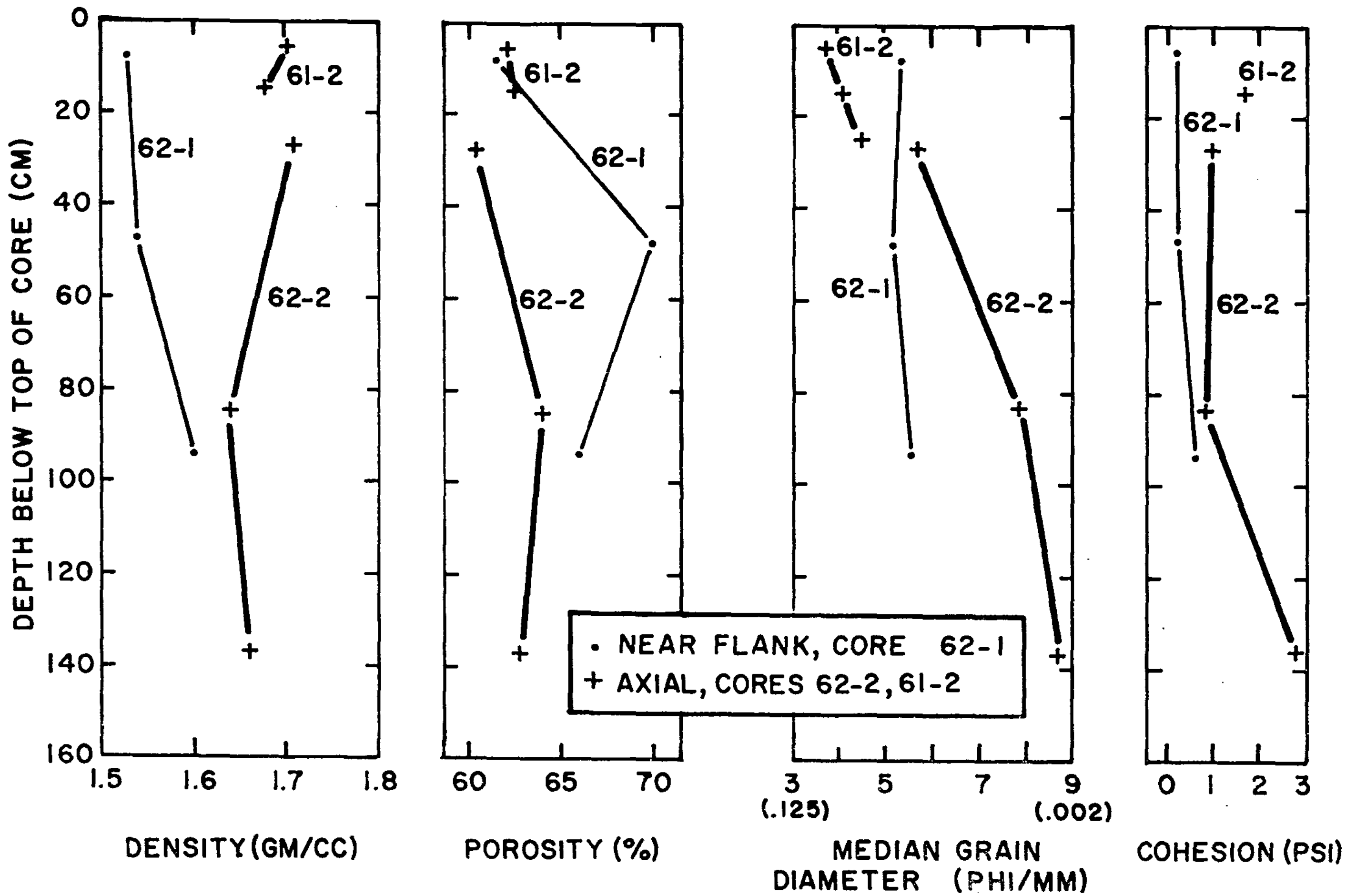

FIGURE 10 COMPARISON OF NEAR FLANK AND AXIAL SEDIMENT PROPERTIES IN THE TONGUE OF THE OCEAN

If it is assumed that the effective reflecting area is equivalent to the first Fresnel zone, the diameter of this zone increases from about 25 feet for the 500-foot level to about 70 feet for the 4500-foot level. Since the dive area contains a sedimentary boundary, it is likely that changes in the reflective characteristics of the bottom could occur within very short distances and, consequently, short time intervals, and could explain the variations present at all levels. For example, assuming a current speed of 0.3 knot the vehicle could drift at a speed sufficient to change the effective reflecting area for the 500 and 4500-foot levels in about 1 and 2.5 minutes, respectively. The pronounced amplitude shift at the 500-foot level took place in about 4 minutes, suggesting that the sedimentary boundary zone may only be 100 feet wide if the vehicle is assumed to have drifted perpendicular to the boundary. The longest period of relatively small fluctuations is approximately 7 minutes and also occurs at the 500-foot level. From this it appears that surface sediment properties are laterally continuous for a maximum of only about 175 feet.

It is also possible that changes in both regional and local bottom slope angle could contribute to the fluctuations and periodic trends; however, it is not known whether the compositional changes associated with the sedimentary boundary are accompanied by changes in large and small scale roughness. It is doubtful that slope angle changes would have a large effect on the fluctuations because of the relatively wide beam of the transducer. It may be that, as an alternate explanation for the periodic variations, the vehicle was drifting across an undulating bottom having a period of about 7 or 8 minutes and different bottom properties associated with the crests and troughs.

For the variety of reasons previously mentioned, it is assumed that compositional changes rather than changes in micro-relief and associated scattering are the prime cause of the observed fluctuations and amplitude shifts. In addition, the mean signal levels at each level above the bottom decrease in accordance with inverse square spreading if an assumed value of bottom loss is used and the amplitude levels are adjusted for differences in gain, indicating that the bottom acted as a specular reflector rather than a diffuse scatterer.

SUMMARY AND CONCLUSIONS

In summary, dives were made aboard the DRV ALVIN to investigate the magnitude of fluctuations present in normal incidence bottom reflected signals at various distances above the bottom. Fluctuations were observed to increase with distance above the bottom and to also become increasingly

periodic with increasing distance. The results indicate that significant changes in bottom reflectivity can occur within a short period of time and that observed amplitude shifts and fluctuations are in all likelihood associated with changes in the composition of the ocean bottom. Additionally, periodic fluctuations observed in the data collected nearest the surface can be explained by assuming an orbital motion of the vehicle. The bimodal frequency distribution of pulse amplitudes measured at 500 feet above the bottom and the close proximity of a sedimentary boundary supports the results of other studies that suggest a relationship exists between the reflective and geologic properties of the bottom, and that echo-sounder pulse amplitude measurements can be used to map major sedimentary boundaries.

It is possible that if a series of bottom reflectivity measurements are made within a short period of time, with a pulse repetition rate that is short compared to the fluctuation period, then the resulting standard deviation of the amplitude variations may be small. Conversely, if a pulse repetition rate that is long compared to the fluctuation period is used the resulting variations may appear to be random.

In general, the results of this preliminary experiment are not conclusive; however, with the experience gained, future dives will be conducted with similar objectives during November 1967 aboard the DRV DEEPSTAR 4000. These measurements will also be accompanied by the collection of supporting environmental data, such as bottom photographs and cores.

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13. ABSTRACT

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